THE

SCIENTIFIC PROCEEDINGS

OF THE

ROYAL DUBLIN SOCIETY.

ol. XII. (N.S.), No. 14. JUNE, 1909.

CHRYSOPHLYCTIS ENDOBIOTICA, Schilb. (Potato-wart or Black Scab), AND OTHER CHYTRIDIACEÆ.

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No. 341

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(PLATES IX.–XI.)

[*Authors alone are responsible for all opinions expressed in their Communications.*]

DUBLIN:

PUBLISHED BY THE ROYAL DUBLIN SOCIETY,

LEINSTER HOUSE, DUBLIN.

WILLIAMS AND NORGATE,

14, HENRIETTA STREET, COVENT GARDEN, LONDON, W.C.

1909.

Price One Shilling.

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XIV.

CHRYSOPHLYCTIS ENDOBIOTICA, Schilb. (POTATO-WART OR BLACK SCAB), AND OTHER CHYTRIDIACEÆ.

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(PLATES IX.–XI.)

[Read MARCH 23. Ordered for Publication APRIL 6. Published JUNE 16, 1909.]

MY attention was first called to the warty disease of potatoes by an article in the *Journal of the Board of Agriculture* (England), entitled, "A new Potato Disease, *Chrysophlyctis endobiotica,* Schilberszky," from the pen of Professor M. C. Potter (1), who, in the beginning of 1903, sent me some spore material. Later in the year, through the late Dr. Maxwell Masters of the *Gardeners' Chronicle,* I got a quantity of warty tubers from Cheshire, from Mr. Newstead, the Curator of the Grosvenor Museum, Chester. I naturally watched with interest the spread of the disease through Great Britain, and its continued non-appearance in Ireland.

Attention in Ireland had been called in 1907 to the dangerous character of the disease, by the publication of an illustrated leaflet by the Department of Agriculture and Technical Instruction for Ireland (2), and early in 1908 by the issue of an Order in Council, giving power to penalize anyone found importing or concealing cases of the disease. Hundreds of samples of scabby potatoes were in consequence sent in for report; but they proved to be either the ordinary scab or Spongospora scab. In October, 1908, however, by the discovery of three cases of warty tubers in Co. Down, Ireland's clean record was lost.

Steps were immediately taken by the Department to stamp out the disease, it need hardly be said. At the end of October, I received from it some of the warty tubers (Pl. IX., fig. 1). Examination of the haulms or "potato-tops" of the diseased plants showed that the trouble was not confined to the tubers, but affected also the branching underground stem (the stolons), and even the fibrous roots. This is in harmony with the observations of Borthwick (3) in Scotland, and of Salmon (4) in Kent, who give excellent

illustrations of the warty excrescences on the haulms at or near the collar. Hence it may be concluded that there is no part of the potato-plant not liable to injury by the disease. This being the case, it follows that no part of the plant should be left undestroyed in attempts to eradicate the disease from an affected centre. It is known that diseased tubers leave spores in the ground, and the diseased shoots no doubt do the same. A diseased tuber is readily recognizable by the coral- or brain-like wart, tumour, or carbuncle on it at one or more points, but especially at the toe or crown end. The wart is a wrinkled proliferation or corrugation of the flesh of the tuber (Pl. IX., fig. 2), due to excessive cell-division caused by the stimulating presence of the fungal parasite. It is apparently an attempt on the part of the host to rid itself of the enemy. Microscopic examination of one of the convolutions of the wart shows the abundance of the resting spores of the fungus (*Chrysophlyctis endobiotica*, Schilb.), (Pl. IX., fig. 3). To the naked eye the first signs of attack of a tuber are observable in the abnormal appearance or malformation of a sprouting "eye." The grey surface of the swollen eye is dotted over with golden-yellow rings, as seen with a pocket lens. The microscope shows that these rings are optical sections of the walls of the resting spores. When ripe these walls become dark-brown, and the whole wart then looks more or less black, giving the term of "Black Scab," or, better, "Black Wart," to the disease. It is unfortunate that Schilberszky's (5) first and only account of the trouble in 1896, good as it is, is brief, incomplete, and unillustrated. His reference to the crater-like excavations of the potato flesh, arising in the later stages of the disease, suggests that the black scab attack he had to deal with was complicated by some other disease such as the deep form of Spongospora scab. Further, except for the knowledge due to Potter, that the trouble, as would be expected, is perpetuated by the resting spores, his account was not added to until November, 1908, when I was able to announce in *Nature* that I had succeeded in making the recalcitrant resting-spores germinate.

Chrysophlyctis is a member of the Chytridiaceæ, a low group of fungi having many points of affinity with the Slime fungi or Myxomycetes, and being, in the opinion of some botanists, the originating group of fungi in general. They are classified partly by the character of their plant- or vegetative body, partly by their mode of reproduction. In the lowest forms the plant-body is a naked plasmodium, and propagation is mostly vegetative: in the highest there are hyphæ, suggestive of a mycelium; and reproduction is sexual as well as vegetative. Chrysophlyctis is a member of the lowest group, the Olpidiaceæ. Its plasmodium is distinguishable in the host-cell by being denser, homogeneous, and finely granular (Pl. XI., fig. 1). It may

be seen abutting on the host-protoplasm, and disputing with it, as it devours it, occupation of the enlarging cell-cavity. The host-nucleus is first affected, turning brown. The protoplasm follows, and then the cell-wall. This, though brown, does not, like the protoplasm and nucleus, disappear. The starch-grains are the last attacked, and remain white and uninjured for some time in an invaded cell. The parasitic plasmodium passes from cell to cell by boring its passage through the host cell-wall. No doubt the parasite secretes the cellulose-dissolving ferment cytase, as well as a toxin to kill the host protoplasm before absorbing it. It is in this stage that it stimulates to active cell-division the surrounding host-cells, and produces the gall or wart.

PROPAGATION.—A. *Swarm or Summer Zoosporangia.*

The parasite not only penetrates through its host from cell to cell by its plasmodium; it also spreads from tuber to tuber, and from plant to plant, by the formation during the growing season of zoosporangia. These are elliptical bodies, with smooth yellowish walls, and numerous zoospores which escape through a hole in the wall, and attack healthy potato-tissue. Schilberszky saw the escape of these spores, and states that they can bore a passage for themselves into neighbouring host-cells, when their discharge is internal. The spores escape readily when the sporangia are placed in water or in macerations, says Schilberszky.

B. *Winter or Resting Sporangia or " Spores."*

As the tuber ripens, the parasite replaces the summer sporangia by resting ones which carry the disease through the winter, and serve to propagate it in the spring. Schilberszky mentions these resting spores, but contents himself by noting their thick, dark-brown walls, described by him as smooth. He leaves to the future an account of their origin, structure, and fate.

The resting sporangia, 30–70 μ in diameter, are very numerous in diseased tubers, and are easily recognizable with a pocket lens (Pl. IX., fig. 3). Under the microscope the wall is seen to be not smooth, but ridged or angular (Pl. XI., fig. 3). These brown ridges or bands form part of a kind of epispore which arises as the sporangium ripens, and seems to be formed from the residual contents of the host-cell when not also from its cell-wall as well. I find W. B. Grove (*Gardeners' Chronicle*, 1905) supports this view in part, in that he says that " though the resting spores are smooth outside, they are sometimes closely invested with the brown angular remnants of the host-cell in which they had formed." The epispore is thus deposited from without, as a third layer on the thickening wall of the sporangium. If this more or less artificial epispore is ignored, then one may speak of the spore-wall as smooth.

Its presence is, however, enough to prevent one from confusing the resting spores of Chrysophlyctis with those of *Urophlyctis leproides*—the cause of beet-tumour, a mistake which has unfortunately crept into mycological literature. As a rule there is only one resting sporangium in a host-cell; occasionally there are two.

Through the dark wall of the sporangium one can see the spongy or granular protoplasmic contents enclosing in the centre a bright body which reagents show to be a large reserve fat globule.

The origin of these resting spores can be traced in microtome preparations (Pl. X., figs. 3, 4, 5). The naked dense plasmodium soon becomes wholly converted into a sporangium which continues to enlarge and to occupy more and more of the enlarging host-cell. Chrysophlyctis is thus holocarpic, and differs from the eucarpic Urophlyctis, in which the whole of the vegetative body is not used up in the production of the propagating organs, as is the case in Chrysophlyctis.

I followed the resting spore from its foundation to complete maturity, but must leave to a future occasion an account of the nuclear and other changes in the developing sporangium, as my results are not yet complete. I may say there are not wanting signs that the small host-cells surrounding the invaded enlarged one may lose their cell-walls in part, and form a sort of symplast round the developing sporangium.

Germination of Resting Sporangium (or "spore").

Judging from analogy and from the examination of preserved sporangia, I concluded the "resting spore" must be a composite body or resting sporangium (Pl. XI., fig. 4). I proceeded to try and rouse it from its winter rest by stimulating solutions of one kind or another, e.g., by :—*A*, 1 per cent. sugar, *B*, 2 per cent. sugar, *C*, *A* or *B* with a trace of the proteid ferment papayotin, *D*, potato juice alone ; and *E*, *D* with papayotin. Cultures in these and in water were kept, as well as macerations, in darkness, in light, at room temperature, and in the incubator at a constant temperature of 20° C., and examined from day to day. I constantly found empty spore-cases with ruptured walls, but for some time failed to see any signs of escaping zoospores. At last the potato juice, exercising possibly a chemotactic influence, gave success; and sporangia with split walls and escaping zoospores were found (Pl. XI., fig. 5). These showed the same sluggish movements observed in the sporangia of certain other Chytridians, disturbed during their resting period. Each sporangium contains hundreds of more or less pear-shaped uniciliate zoospores. As the zoospores are being formed, the large central fat globule disappears, being broken up into innumerable minute globules which are

absorbed by and reappear in part in the individual developing zoospores. When looking for sprouting sporangia, I had an experience one day (20th Nov., 1908) of sufficiently general interest to deserve a detailed account. I saw several zoospores rushing very rapidly backwards and forwards through the field of the microscope. I found next an elliptical sporangium with a small hole in its wall at one end. The sporangium was practically full of zoospores swarming most vigorously and crowded round the opening in the wall in what looked like a general wild rush to be amongst the first to escape into the fresh air dissolved in the surrounding water. Within a minute the sporangium was emptied. The motion of the zoospores through the field of the microscope was comparable to that of a mouse in a room; and the rough analogy is not lessened by the fact that the pear-shaped zoospore moved with its single cilium behind. Some of the zoospores were caught between the glass-slide and cover-slip and became stationary. The body of the zoospore (1·5–2·4 μ in diameter) was actively amœboid, going through changes of form too rapid for me to sketch in succession (Pl. XI., fig. 6). The cilium remained either straight or became curved like a carriage-whip, and usually moved passively with the body of the zoospore, though it also showed slow sweeping movements backwards and forwards. Suddenly the body would be seized with a violent spasmodic fit, shake itself free (or not) from its temporary imprisonment, and swim away. The amœbidity of the body of the zoospore and comparative passivity of the cilium were striking.

My letter to *Nature* in November, 1908, announcing the observation of the multisporous character and the germination of the resting sporangia, called forth a letter from E. F. Weiss recording his observations of germinating spores in August. The time of the year suggests that these must have been the summer ones whose germination Schilberszky had already described. The resting ones do not, in my experience, germinate with ease in potato-juice, as Weiss found his sporangia to do. If they had done so, I should not have spent three months in examining them day by day under various conditions.

Marchal had the same difficulty with the resting spores of the Chytridian *Asterocystis radicis*. He saw the escape of the zoospores from the summer sporangia readily, but failed to make the resting ones germinate, though he found them from time to time in his cultures ruptured and empty. This is equally true of the resting spores of *Olpidium brassicae*, the cause of "black leg" in young cabbages. It looks as if, judging from Chrysophlyctis, resting spores must be cultivated in a decoction of or in immediate contact with the host-plant, that its chemotactic influence may be exercised on them to arouse the zoospores to activity. Summer sporangia sprout without difficulty in water material in most Chytridians.

Penetration into Host.

As our knowledge stands at present we are left to hypothesis to account for the entrance of the parasite into the potato-plant. The general assumption is that the zoospore, whether it comes from the summer or the resting sporangium, on reaching the potato-tuber, bores its way into the young epidermal cells of the tuber at one of the eyes, and there begins its destructive work.

Massee (7) holds that the parasite is an epidermal one only, and that when the resting spores appear deep-seated, it is due to the depression of the infected epidermal cells by the division aroused in the surrounding cells. It is, I think, necessary to distinguish between the resting eyes of a ripe tuber in the autumn and those of one sprouting in the spring. The autumn eye is small, dormant, and protected; the spring one exposes its delicate tissue to attack when sprouting, and would more easily fall a victim to marauding zoospores.

In my winter material I found tubers showing quite small, slightly warty eyes. Examination of these showed them to be full of the parasite, not only of its well-developed resting spores, but of the plasmodium also (Pl. IX., figs. 5, 6). Some of the leaves in the shoot forming the eye are, as the figure shows, riddled by the resting spores, and practically destroyed. Examination of the cortical cells of the tuber in the region of the eye, and beneath the protecting cork layer, shows that these cells are occupied by the parasitic plasmodium, which is, as Schilberszky states, thus subperidermal.

The condition of affairs is such that one cannot imagine the parasite can have obtained its thorough hold of the eye by simple penetration of zoospores from without. It is more reasonable to conclude that (as I have already shown in the case of the Spongospora scab (8) of the potato) the black scab, or warty disease of the potato, is propagated, not only by the contact of healthy tubers with spores in the soil, but by the internal passage of the plasmodium from diseased tubers into the potato-tubers formed from them as seed, the next year. On the 6th November, 1908, I inoculated tubers, and slices of tubers, with decoctions and macerations of spores. The tubers were kept in darkness in sand at room temperature. The eyes have sprouted, and though the shoots now (11th March, 1909) show discolouration, it is too early to say if infection has taken place. I also placed a number of warty tubers under somewhat similar conditions, exclusive of the sand. In their case the eyes have sprouted a little; and the new material in them shows an almost continuous "coating" of the resting spores, which could scarcely have arisen except from within. The vascular tissue of the tuber, in connexion with the eye, was slightly yellow, as if discoloured. It is this last-mentioned mode of propagation, i.e.

by warty seed-tubers, which, I think, accounts for the outbreak of black wart in Co. Down. Kilkeel, one of the disease-spots, is an important fishing-village on the coast, with considerable intercourse with the English and Scotch coasts, from which slightly diseased tubers could easily be imported, unnoticed by the buyer.

The warty disease was reported from Germany in the autumn of 1908, and is now known from various districts in Westphalia and the Rhine Provinces. It would appear from reports in the *Deutsche Landwirtschaftliche Presse* (30th Sept., and 17th Oct., 1908), and the *Illustrirte Landwirtschaftliche Zeitung* (2nd Dec., 1908), copies of which I have received from Dr. Riehm, that, as in Cheshire so in Germany, the disease was left unnoticed and unreported for several years before the attention of botanists was called to it as an increasingly troublesome pest. The tendency in Germany, judging from the articles, is to regard the disease as not very serious, since it is confined, it is stated, to small garden-plots, where potatoes are grown year after year in the same ground. Germany would make a serious mistake if it treated the outbreak of the disease with indifference. This, I know, its mycologists will not do. It needs only a very casual acquaintance with the facts of the case in the British Isles from the time of the discovery of the trouble by Potter in 1902 to the present time to warn one of the necessity of taking all possible steps to stamp out a disease which may become as serious as ordinary leaf-blight, and less amenable to treatment.[1] The soil, manure, and weather are not considered in Germany as predisposing causes. The disease, most marked in the variety Magnum Bonum, called locally Stüpmoll, is attributed solely to want of rotation in the crops. It is called locally canker,[2] and is believed to induce cancer in eaters of diseased tubers. There is no evidence of this connexion.

AFFINITIES.

Chrysophlyctis endobiotica is a member of the group Olpidiaceæ, and is allied to *Asterocystis radicis*. Massee regards it as a Synchytrium, basing his opinion on :—

(*a*) The epidermal nature of the parasite.

(*b*) The presence of an enveloping membrane round the protruding contents of the sporangium.

I have already shown that, though the parasite may enter the potato, in some cases, at the epidermis, it is not its only seat, and that it may occur in a deep-seated position, even below the cork.

[1] The only redeeming feature in connexion with the disease is that its germs do not, so far as we know, spread aërially in the growing crop.

[2] In some parts of England it is called "cauliflower."

I have never seen the enveloping extruded membrane mentioned, in any fresh, ruptured sporangium. The wall ruptures; and the zoospores escape without any sign of the extrusion of a membrane. This is not, however, the case in artificially preserved material. I hardened a rotting piece of potato-wart, kept for some time under cultivation in potato-juice, and full of resting sporangia, in Flemming's solution, and then stained it by the three-colour method. On squeezing under the microscope a sporangium isolated from the general mass, its outer wall burst, and the contents as separate zoospores were extruded, enclosed by the inner wall as a hyaline membrane (Pl. IX., fig. 7). The persistence and protrusion of the inner wall as a membrane thus seem to be due to the artificial preservation of the same by reagents. If the existence of this protruding membrane in nature could be accepted, it would not indicate Synchytrium affinities. The membrane in Synchytrium is an external one, and envelops a sorus of 150 or more sporangia. It is quite different from the inner wall of the single sporangium. This no more protrudes in Synchytrium than in Chrysophlyctis. My figure of the sporangium is, in all essentials, like that of *Synchytrium taraxaci* (fig. 8e), figured by A. Fischer (9). His figure 8c (p. 46, o.c.) shows the membrane enveloping the sorus of sporangia in *S. Mercurialis*.

Prevention of the Disease.

It is stated that the disease first appeared in 1896 in Birkenhead district, and that it was brought there in Continental cattle-boats. It is now found in many different districts in England, Wales, and Scotland. It is often so pronounced as to destroy the whole crop, and it is not confined to garden-plots. Warty tubers are naturally poorer in food-matter than healthy ones, and when not destroyed in the field do not keep well in store. They ought to be destroyed as soon as found, and on no account saved for seed. The most that can be done with them is to boil and feed them to pigs. The haulms should be gathered and burnt. Infected land should be kept free from potatoes for possibly seven years. The application of kainit or other potash-manure and of phosphates, the close inspection of seed-tubers, and the avoidance of low-lying or undrained land should prove beneficial in preventing a recurrence of attack. In keeping with the known aquatic habits of the Chytridiaceæ as a group, a wet undrained potato field would be a predisposing cause, favouring the spread of potato-wart. This is true of flax-yellowing due to *Asterocystis radicis* Wilde., of lucerne-canker in South America, due to *Urophlyctis alfalfæ*, and of cabbage black-leg due to *Olpidium brassicæ* in North America, all diseases caused by Chytridiaceæ. Curiously enough, I have seen only one reference to the bearing of the condition of the soil on cases of potato-wart, and have

not myself visited the Irish centres of disease. The west of Ireland, which has potato-troubles enough, would, I am afraid, prove ideal ground from the parasite's standpoint for the spread of the potato-wart.

I am trying the effects of soaking warty tubers in such fungicides as corrosive sublimate and formalin, as well as Bordeaux mixture; but I think it would be better to destroy the tubers outright when the tumour is obvious. In some cases the tumour could be broken off by its narrow neck of attachment and the potato eaten, though even this might prove false economy. Gas-lime applied in May or June, and sulphur mixed with the soil, in probably non-paying quantity, destroy the pest in the soil.

BEET-TUMOUR, *Urophlyctis leproides*.

Another Chytridian of considerable biological interest causes tumours on the bulb or root of the beet[1] or mangel, *Beta vulgaris* var. *rapacea*, in Algiers, where it was discovered in 1894 by Trabut (10), and was called by him *Entyloma leproides*. Saccardo regarded it as a Smut, and placed it in the Ustilaginaceæ as *Œdomyces leproides*—a view supported by Prillieux and others. Magnus, however, in 1897, in the "Annals of Botany," records it as a Chytridian under the name of *Urophlyctis leproides* (11); and, curiously enough, falls himself later into the error of ascribing potato-wart to it, as do Massee and others.

Urophlyctis is an interesting genus which causes aërial galls on some plants, such as clovers, Umbelliferæ, and Chenopodiaceæ, and root-galls on others, e.g., lucerne and beet. The gall is in some a much-enlarged epidermal cell, almost surrounded by many layers of other cells. In others the cavity containing the spores is added to by the ramification of the original cell through the gall-tissue, accompanied or not by sieve-like perforations or by complete absorption of the walls of the adjoining attacked cells. According to Prillieux (12), in *Urophlyctis leproides*, the cavities containing the spores are formed by the hollowing out of the thin-walled parenchyma, forming the fleshy tumour in which the spores accumulate. It is assumed, I think naturally, that Prillieux means to imply that the hollowing out is due to the breaking down of the walls of the surrounding cells. Magnus does not accept this view of the origin of the cavities in the flesh of the tumour. He considers that the cavities or cysts in a swelling or lobe of a tumour are all connected and derived from one original cavity or host-cell which sends out, when invaded, processes. These ramify through the substance of the swellings, remain in connexion with the parent cell, and

[1] The beet-tumour I examined from Co. Wexford showed no spores, and was not, as I at one time thought (*Jour. of Dept. of Agric.*, i., 1902), caused by *U. leproides*. The statement got into print before I could suppress it.

form numerous other spore-containing cavities by enlargements of the processes. One must imagine a beet-cell when attacked sends out living diverticula, which make a passage for themselves between the other surrounding host-cells (stimulated thereby to division), and sooner or later dilate to form the cavities or cysts, the whole being thus one malformed host-cell. Through the kindness of M. Trabut, I have been able to examine some of the original material, and find myself unwillingly compelled to differ from Magnus. Serial sections show the layer or layers of cells between adjoining cavities broken or in the act of breaking down. Thus the cavities containing the spores are due, I take it, at any rate in part, to the disappearance by absorption of the surrounding host-cells. They are therefore lysigenetic in origin, as is the case, to a certain extent, in *Urophlyctis pulposa* (Wallr.) Schroet., and *U. major* Schroet., and still more so in *Urophlyctis Rübsaameni* Magn. (13). This is a point of considerable interest. In 1895 von Lagerheim reported the occurrence of galls on the roots of Lucerne (*Medicago sativa*) in Ecuador. These galls were caused, he stated, by the same fungus as that responsible for the beet tumour. In the "Berichte der deutschen botanischen Gesellschaft" (14) for 1902, Magnus describes the same root-galls on lucerne material received from Behrens from Colmar in Alsace, and finds certain points in which the lucerne gall differs from the beet one, sufficiently important to justify him in describing the lucerne fungus as a distinct species under the name of *Urophlyctis alfalfæ* (von Lagerheim olim) Magnus. The chief distinction is that in *U. alfalfæ* the walls between the cavities in the gall are broken down, thus putting adjoining originally independent cavities into connexion; while in *U. leproides*, as already stated, no such dissolution of septa, according to Magnus, occurs. My material, however, shows such collapse of the separating partitions, and thus *U. alfalfæ* as a distinct species must rest, if I am right, on other grounds. Interesting in this connexion is the illustrated account by S. Kusano (15) of a cyto-pathological study of *Synchytrium puerariæ*. The parasite is chemotactically attracted to the deeper tissues of the host, avoiding, though a Synchytrium, the epidermis and the green cortical cells. Its plasmodium develops in the host-cell. Both increase much in size. The surrounding host-cells lose their walls and form a symplast, enveloping the developing Synchytrium sorus, which, at first intracellular, in the end lies in a lysigenetic intercellular space.

Origin of Resting Spores in Urophlyctis.

The resting spore of Urophlyctis is a smooth, thick-walled body, comparable to a plano-convex lens in section. From the centre of the flattened side a small papilla may project. There are two distinct views as to the origin of these spores. Magnus has described in *U. leproides* and other

species the presence of two distinct mycelia—one giving small male organs or antheridia, the other, larger female receptive organs or oogonia. The antheridium becomes connected by a narrow canal with the oogonium, and fertilization occurs. The resting spore is thus an oosperm or zygote. Fischer, on the other hand, says in Urophlyctis there is no act of fertilization. The resting spore is the terminal cell of a hypha which also forms, just below it, an accessory or collecting, more or less swollen cell, which becomes less conspicuous as the resting spore develops. Magnus's views on *U. leproides* are based, he states himself, on the spirit material he received. I have not seen any illustration of the female mycelium he describes beyond the indistinct structure he shows (op. cit., figs. 29 and 33, *U. leproides*) and calls "the remains of the carrying threads [or mycelium] of the receptive cells." In his paper on *U. Rübsaameni* Magnus considers 'as the remains of the host-cells' tufts of short appendages described as protoplasmic threads or appendage-threads by Schroeter and Büsgen. These occur often at the same point on the convex side of the resting spore in *U. Rübsaameni*, as his remains of the female mycelium in *U. leproides.* If I am correct in my observations that in *U. leproides* the host-cells become disintegrated as the tumour enlarges, may not the *U. leproides* remains also be those of its host-cells? In the examination of the spirit-material of *U. leproides* at my disposal, I have seen nothing to support the view of the sexual origin of the resting spores in Urophlyctis.

FLAX-YELLOWING.

The flax crop, almost wherever it is cultivated, is liable to be troubled not only by the yellow rust *Melampsora lini*, but by a more serious form of yellowing, called in Belgium *le feu* or *la brûlure*, due to a member of the Chytridiaceæ, *Asterocystis radicis* Wild., the life-history of which, so far as it is known, was made out by E. Marchal (16) in 1892. I have received flax-yellowing due to it for report from various parts of Ulster. The disease appears in wet, low-lying parts of the field, and is indicated by the premature yellowing of the seed- and other lower leaves of the young plant. The stem loses its firmness, and its tip topples over towards the ground. The roots have a peculiar glassy, flabby appearance, and are easily pulled out of the ground. The parasite is confined to the roots, attacks the root-hairs and the roots generally, leaving only the central cylinder untouched. Thus the yellowing of the foliage is caused by the choking up and destruction of the absorbing tissues of the roots, i.e., to starvation of the plant by the interference of the parasite. This occurs as a plasmodium in the host-cells, and passes, in a way at present conjectured only, from cell to cell in the root, reproducing itself by swarm-sporangia like those of other Chytridiaceæ. These sprout

readily in water, and form the usual uniciliate zoospores, which in wet soil infect neighbouring roots, probably through the root-hairs. Marchal found, e.g., that the zoospores spread the disease a distance of 20 cms. (8 inches) in all directions in 24 hours.

Resting sporangia are common in older plants, and have been shown to be the means of propagating the disease from season to season, though their actual germination has not yet been observed.

Flax-yellowing is a disease of youth. The critical period of attack varies between the thirteenth and twenty-fifth day after the time of sowing, and is partly dependent on the weather, especially the temperature. Asterocystis occurs also on the roots of grasses, and of many weeds found in a flax-field. Its eradication depends mainly on crop-rotation (in which flax comes once in seven or even ten years), helped by the pulling up and burning of the diseased plants. Flax soil, says Marchal, should not receive excess of nitrogenous manure, but a sufficiency of phosphoric acid. The extensive manurial experiments carried out by the Irish Department of Agriculture each year since 1901 demonstrate "that as regards artificial manures potash should be the dominant, if not the sole, manurial ingredient in those used for flax." Muriate of potash, at the rate of 1–1¼ cwt. per statute acre, mixed with sand, fine soil, or sawdust, is recommended for application (17). The Department finds that this potash manure prevents flax-yellowing in Ireland, and, as a result, for the last two or three years very few cases have come in to me for report. Marchal, however, found the zoospores of Asterocystis bore easily a dose of 0·02 per cent. (1 in 5,000 parts) of potash in their food solutions or in soil.

Marine Chytridiaceæ.

I have collected from various parts of the coast of Ireland algæ infested with Chytridians. One of these, on a species of Ectocarpus, was described by Dr. E. P. Wright (18) as *Rhizophidium Dicksonii.* In his monograph of the group, A. Fischer says of this species the sporangia are of very abnormal form; and the relation of the parasite to its host seems to deserve fresh investigation, as its sporangium appears, from the figures, to lie partly within the host-cell. Rhizophidium Schenk shows an external sporangium and an internal rhizoidal or haustorial mycelium. My intention to act on Fischer's suggestion by an examination of the collected material was anticipated by P. Magnus, who gives the results of his examination in Hedwigia in 1904, N. Wille having already in 1899 decided that the plant was not a Rhizophidium, as it possesses no signs of a mycelium. He called it *Olpidium Dicksonii.* Magnus, it seems, had the plant before him in 1875 (two years before Wright's account appeared), when describing the Marine Olpideæ, but left it unnoticed for the time being. He now regards it as

ıe representative of a new genus which he calls *Eurychasma* (*Eurus* broad, *kasma* a slit). It lives entirely in the interior of the host-cell attacked, does not produce rhizoids (i.e., it has no intramatricular mycelium), and its whole vegetative body becomes converted into a zoosporangium. It is thus holocarpic. Resting spores are unknown. It differs from the other Monolpidiaceæ in which Wille placed it by the mode of dehiscence of its sporangium. This splits open and forces apart the cell-wall of the host-cell, projects through the opening made, sends out one or two slight prominences, the ends of which open to allow its zoospores to escape. *Eurychasma Dicksonii* (Wright) Magnus is the only species. It is very widely distributed, and has been recorded from the coasts of Ireland, Scotland, Norway, and from the Adriatic. It grows on many species of Ectocarpus, on *Pylaiella littoralis*, and on *Striaria attenuata*. Hauck found it in localities in the Adriatic where the sea-water was not pure. Fischer states that the Chytridians prefer pure water, and that when, e.g., cultures of decaying algæ which Chytridians are destroying begin to smell badly, the Chytridians themselves are soon destroyed. Macerations are, however, recommended by several observers for the germination of the resting spores.

Olpidium sphacellarum Kny is another marine form not uncommon on species of Sphacelaria from various parts of the Irish coast, and hitherto unrecorded. It occurs in the apical cells of the main and side shoots of Sphacelaria and Cladostephus. Its sporangia, one to nine in each cell, are rounded or flattened by pressure, have a smooth wall and a quite short projecting emptying-neck. Resting spores are unknown. The host-cells attacked cease dividing, become club- or pear-shaped, and their contents, when not absorbed, turn brown or blackish.

No group of plants has more frequently led to error than the Chytridians which simulate the reproductive organs of the marine algæ. I have to confess myself at fault (19) in describing a Chytridian, possibly this Olpidium, as the sporangia of *Desmarestia ligulata*, which thus still awaits the discovery of its reproductive organs.

The following list of Chytridiaceæ on marine algæ, given by A Fischer (op. cit., p. 26), may be of use to Irish students :—

Olpidium bryopsidis on Bryopsis.
„ *aggregatum* in Cladophora.
„ *sphacellarum* Kny.
„ *entosphæricum* in Bangia and Hormidium.
„ *tumæfaciens* in Ceramium.
„ *plumulæ* in Antithamnion plumula.

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PLATE IX.

Fig. 1. Potato-tuber showing pronounced wart at toe or crown. The malformed sprouting eye and roots may be seen in the midst of the distorted tissue. (Natural size.)

Fig. 2. Section through the convoluted surface of the wart showing numerous 'resting spores.' (Magnified.)

Fig. 3. A macerating piece of the wart showing numerous 'resting spores' as black dots. (Slightly magnified.)

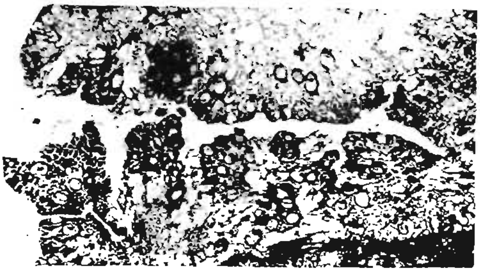
Fig. 4. Microphotograph of a single resting sporangium, showing the angular wall and the separate zoospores.

Fig. 5. Vertical section through a diseased eye

Fig. 6. The same more highly magnified.

Fig. 7. An artificially ruptured sporangium, from Flemming-fixed material
The individual zoospores are clearly recognizable.
The mass of zoospores is enclosed by the inner wall as a membrane, and to the left the dark edge of the ruptured outer wall is just visible.

1.



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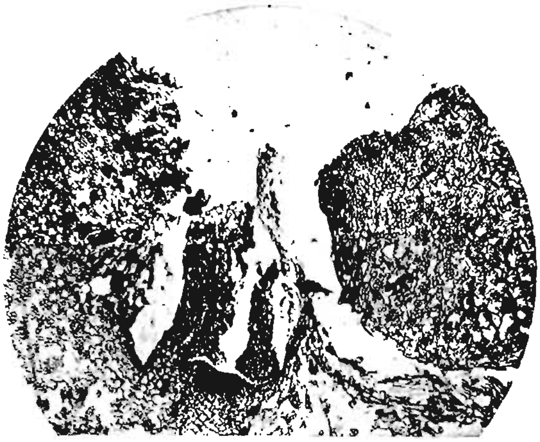

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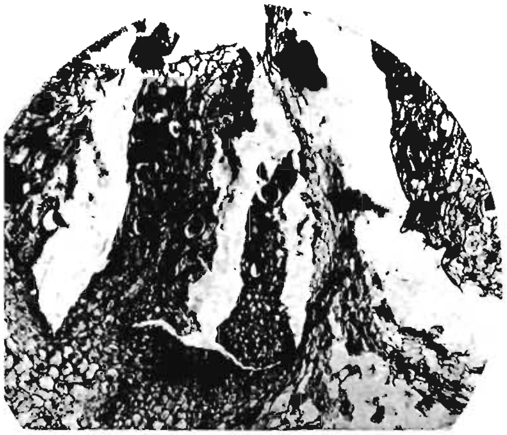

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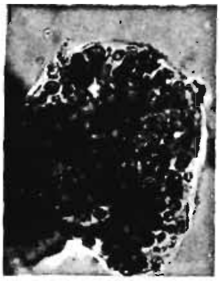


7.

EXPLANATION OF PLATE X.

PLATE X.

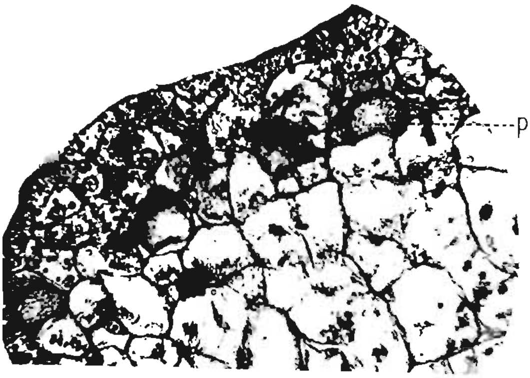
Figs. 1 and 2. **Microphotographs of the same sporangium at two different levels.**
In fig. 1 the zoospores are just recognizable as distinct.
In fig. 2 the slit-like rupture of the wall of the sporangium is seen.

Figs. 3 and 4. Microphotographs of vertical sections of a young wart convolution showing early stages of infection and of intracellular sporangium.
n is the host-cell nucleus.
p is the parasite.

Fig. 5. Microphotograph of two resting sporangia, showing their central vacuoles normally occupied by one or more fat globules. In the sporangium to the right the multinucleate condition is clear.

1.

2.



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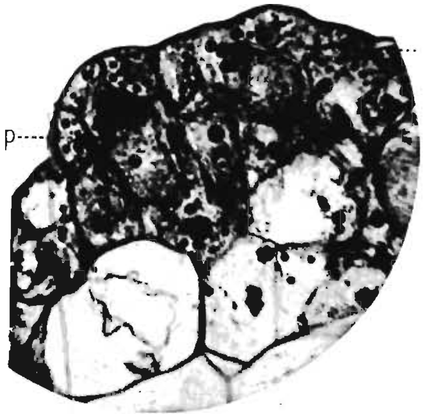

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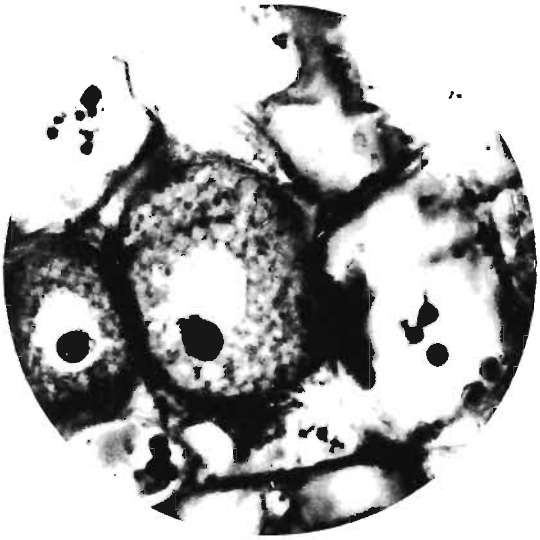


5.

PLATE XI.

Fig. 1. a, b, c. Three different host-cells, showing their nuclei and the intracellular parasite.

Fig. 2. A resting sporangium in development. Wall and fat globules omitted. (× 2000.)

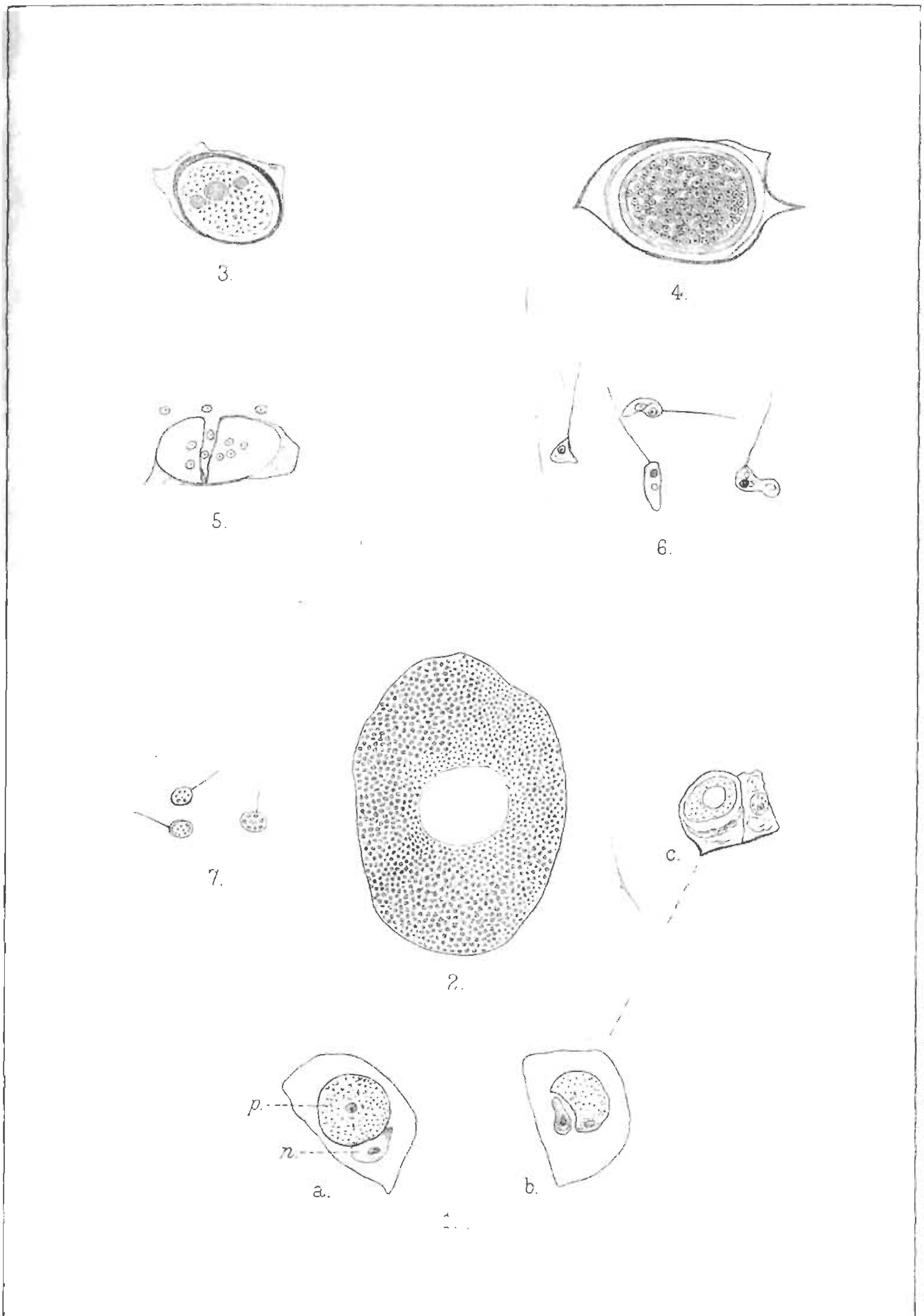
Fig. 3. A ripening resting sporangium, showing the zoospores forming, and three fat globules.

Fig. 4. A resting sporangium cultivated in potato juice. The individual zoospores are shown.

Fig. 5. A ruptured sporangium from potato-juice culture. A few laggard zoospores are shown.

Fig. 6. Escaped zoospores, showing amœboid changes and the single cilium. (× 2000.)

Fig. 7. Zoospores seen in the resting sporangium. Flemming-fixed and stained material.



West, Newman lith.